Combined performance of Jets at the ATLAS detector

Jacob Rawling on behalf of the ATLAS collaboration

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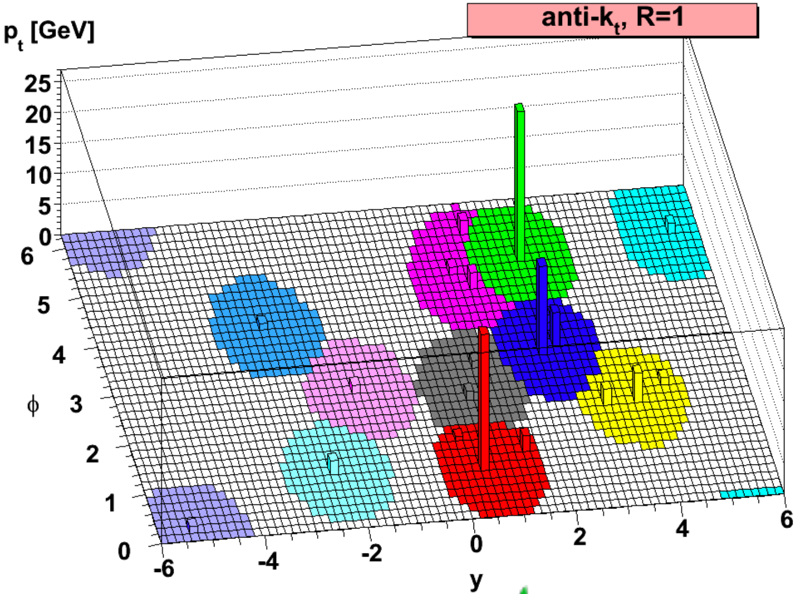
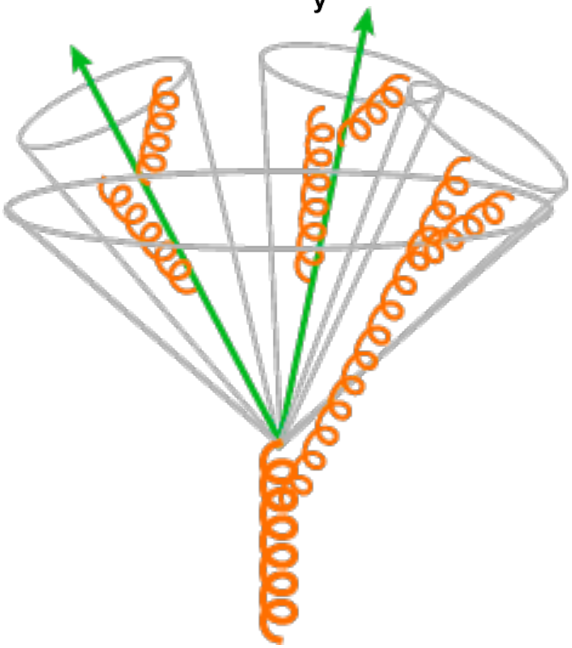
Theoretical vs Experimental jets

The jets we want

- Sequential recombination algorithms
  - IRC safe anti-kt jets
  - Parton-hadron duality

- Perfect knowledge of clustered four-momenta





Theoretical vs Experimental jets

The jets we want	The jets we measure

The jets we want

- Sequential recombination algorithms
    - IRC safe anti-kt jets
    - Parton-hadron duality
- Perfect knowledge of clustered four-momenta

The jets we measure

- **Different energy scales**
    - Hadronic decays measured at EM scale
    - Not all of the jet is measured
- **Mis-measurement:** Dead material/ energy deposits below the threshold
- **Pile-up:** Jet washed out by sea of other hadronic activity

Jet calibration

Calibration Chain

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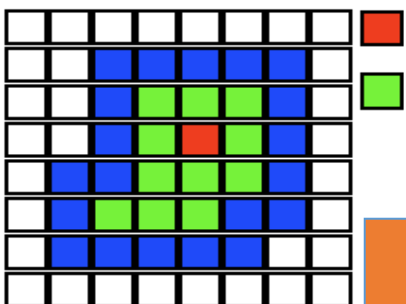
EM or EM particle flow constituent → Jet area based pile-up correction → Residual pile-up correction →

→ Absolute MC-based calibration → Global sequential calibration → Residual in-situ calibration →

Jet inputs



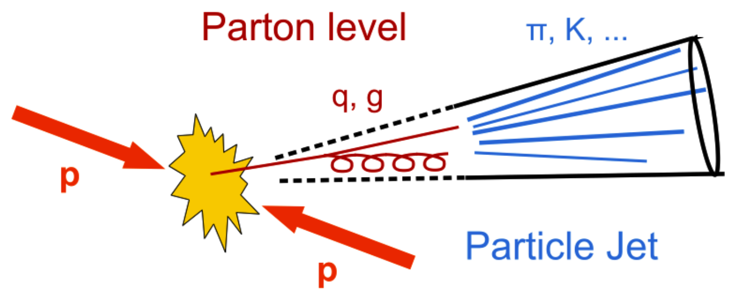
$|E_{\text{cell}}| > 4\sigma_{\text{cell}}$

$|E_{\text{cell}}| > 2\sigma_{\text{cell}}$

EPJC 71 (2011) 1-59

- 3D Topological clusters
- Particle flow objects
- Anti-kT R=0.4 or 1.0 jets
  - Trimming with R=0.2, f=0.05 for large-R jets

The jets we want



- MC truth level
  - Clustered detector-stable particles
- No pile-up
- Muons and neutrinos not clustered

Calibration Chain: Pile-up Correction

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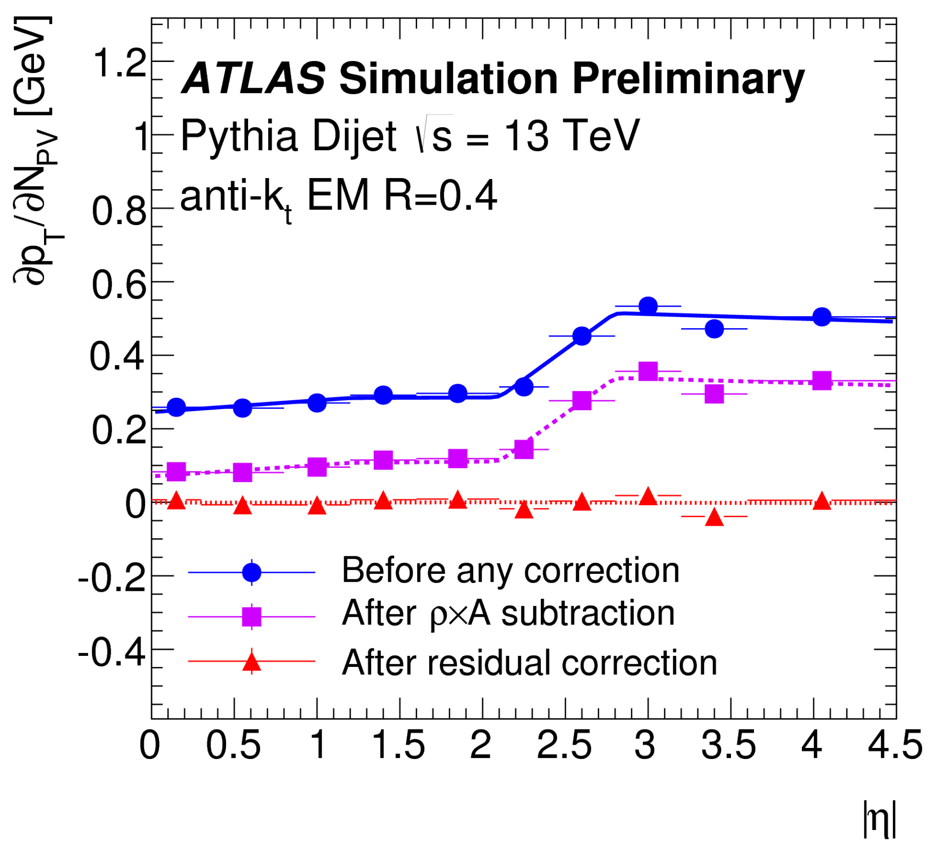
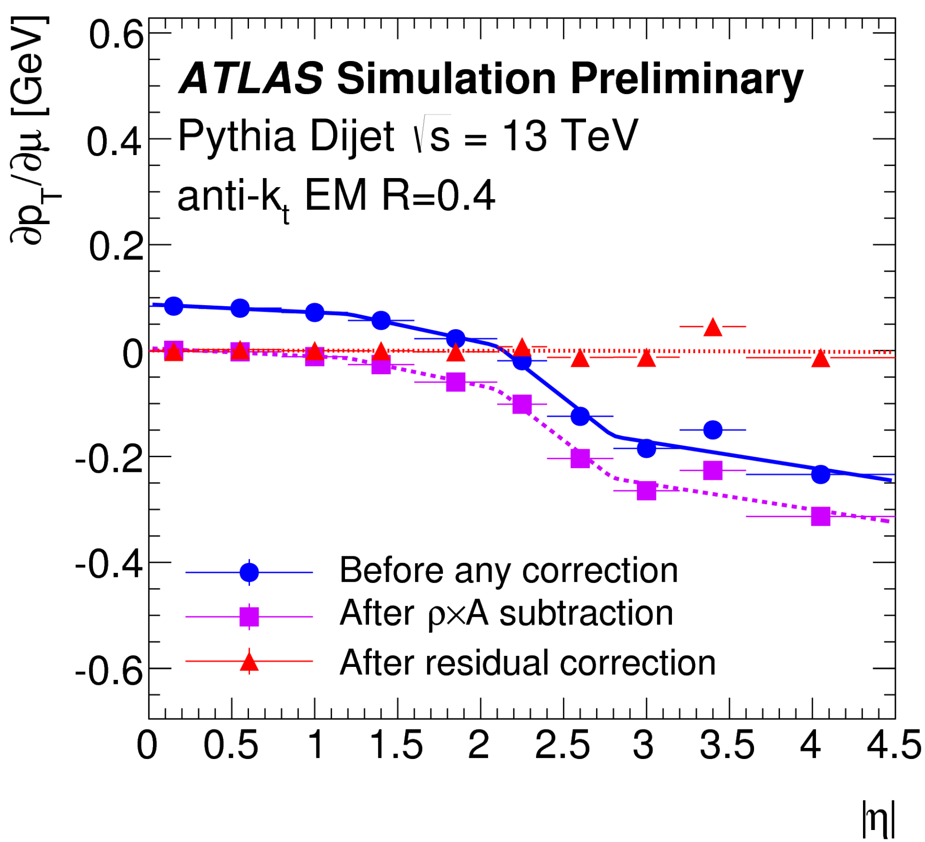
EM or EM particle flow constituent → Jet area based pile-up correction → Residual pile-up correction → Absolute MC-based calibration → Global sequential calibration → Residual in-situ calibration

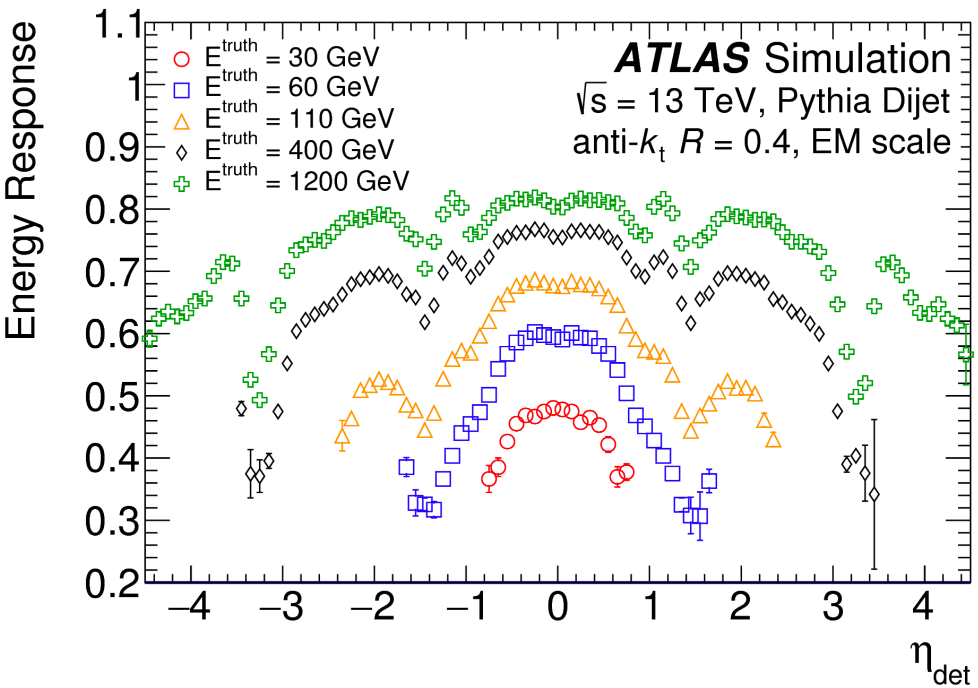


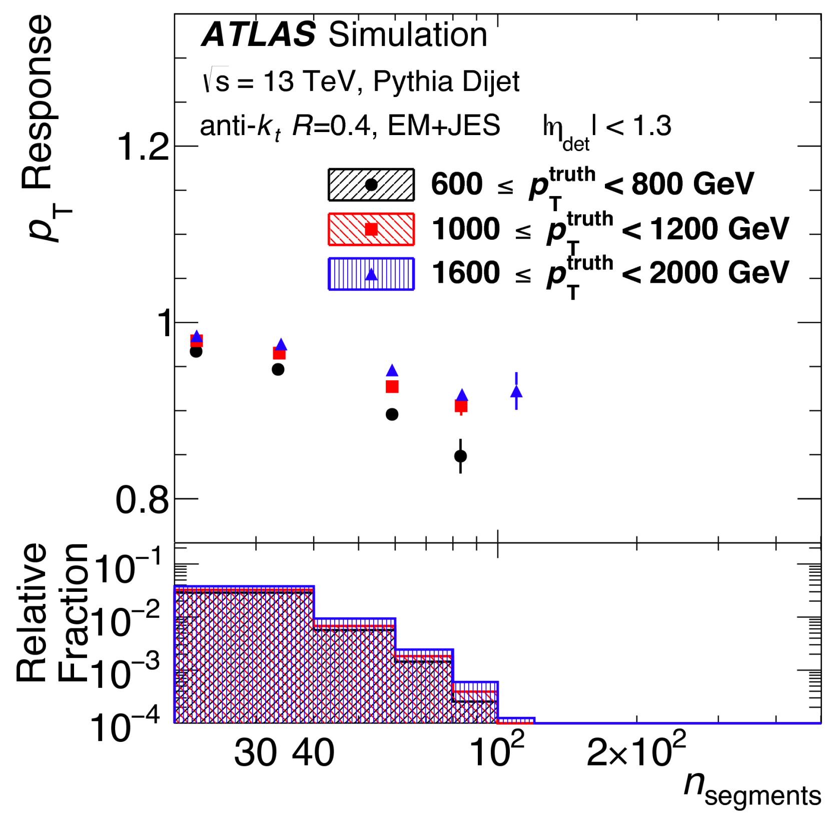


Calibration Chain: MC JES and η correction

EM or EM particle flow constituent → Jet area based pile-up correction → Residual pile-up correction →

→ Absolute MC-based calibration → Global sequential calibration → Residual in-situ calibration





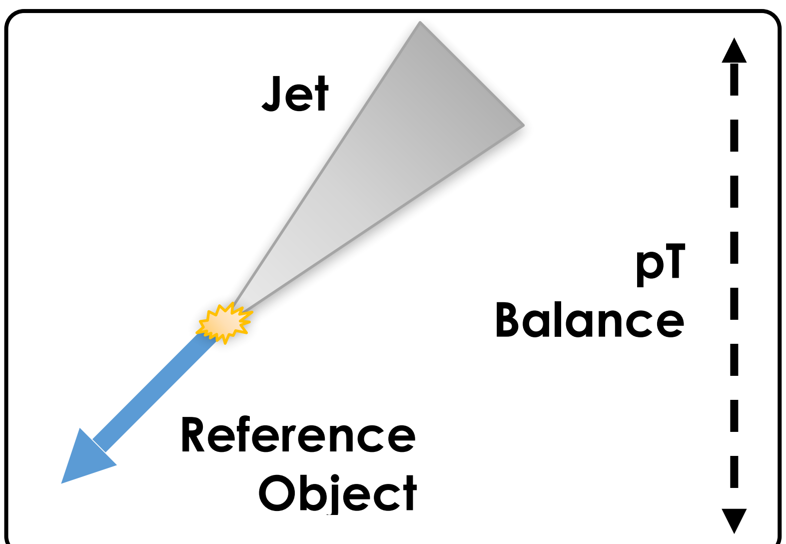
Calibration Chain: In-situ

EM or EM particle flow constituent → Jet area based pile-up correction → Residual pile-up correction → Absolute MC-based calibration → Global sequential calibration → Residual in-situ calibration

Dijet η Inter-calibration → Z/γ+ jet Balance → Multi-jet balance

η Inter-calibration

Jet Energy Calibration



Relative Response, $R = \frac{p_T^{\text{probe}}}{p_T^{\text{ref}}}$

Calibration factor, $C = R^{\text{MC}}/R^{Data}$

Dijet in-situ η inter-calibration

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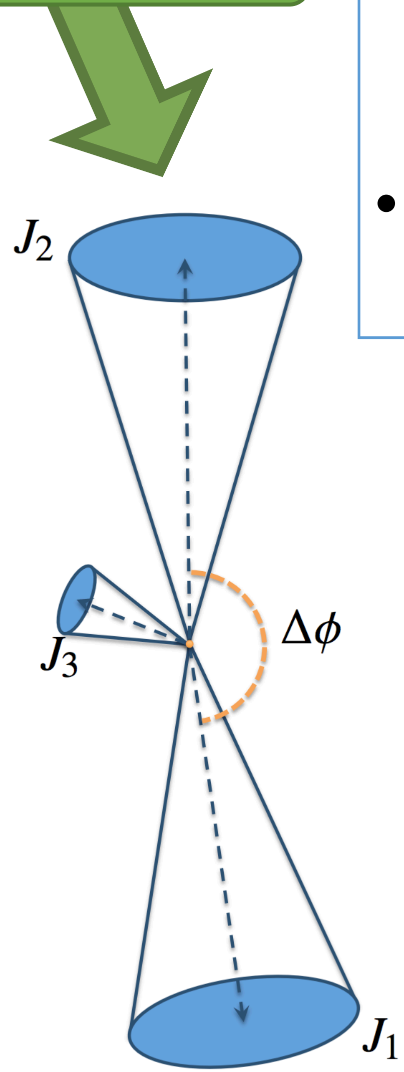
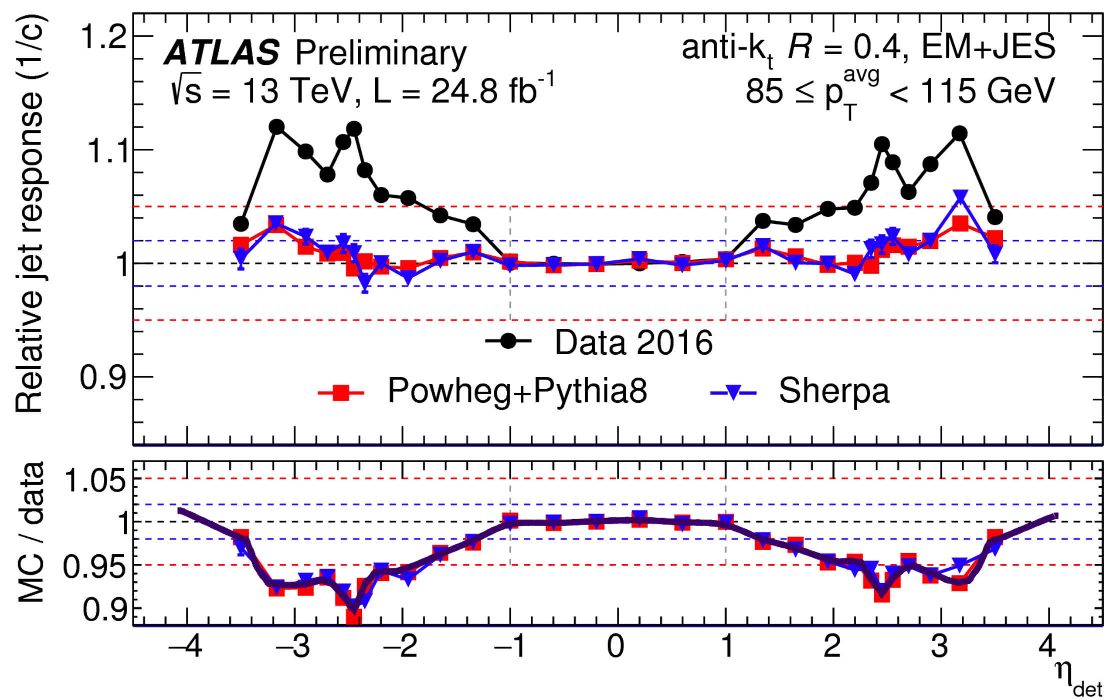
Dijet η inter-calibration



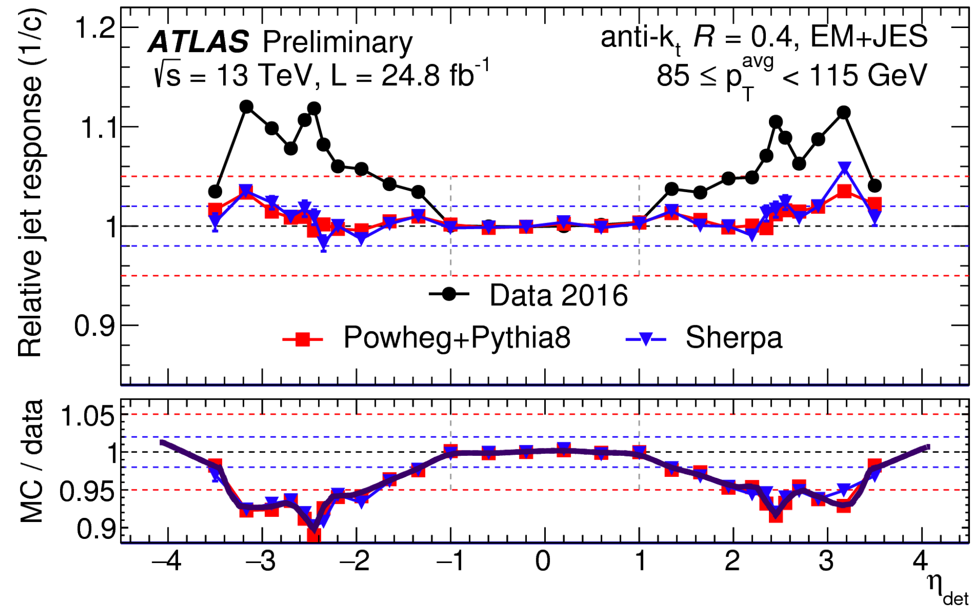
- **Reference object is a jet**
  - Use multiple reference regions and solve set of ~25 linear equations simultaneously
- **Why?**
  - Correct for η dependent detector mis-modelling

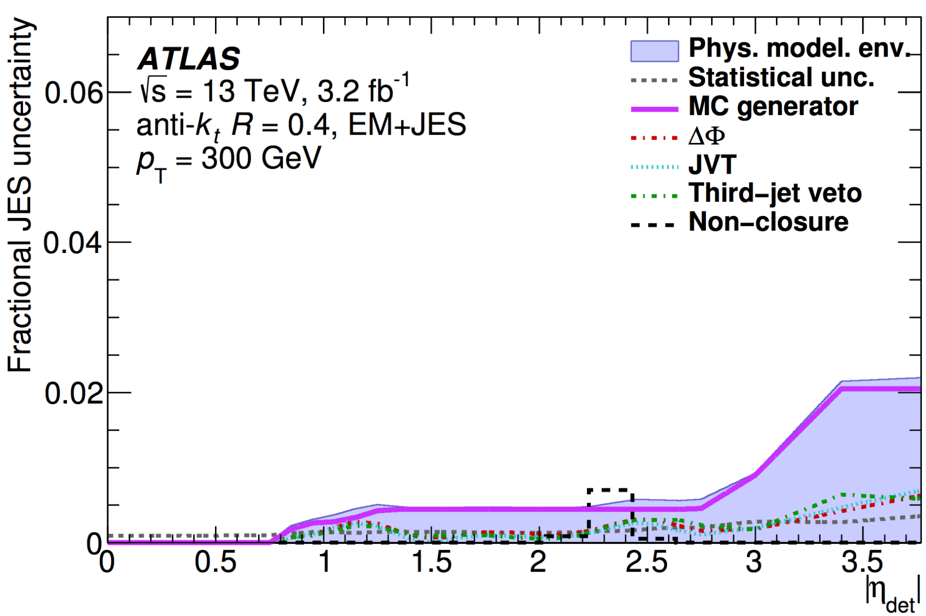


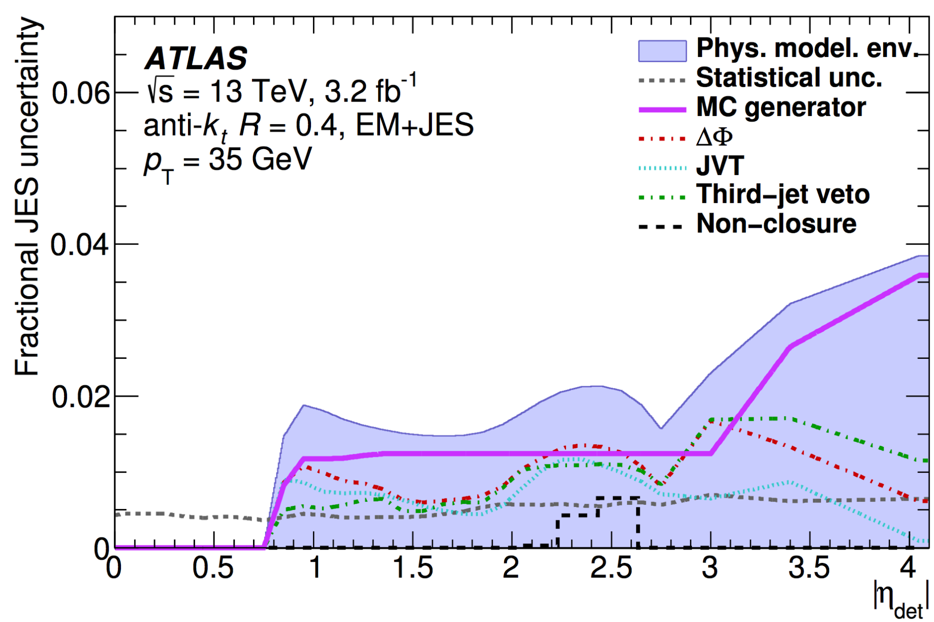
Dijet in-situ eta intercalibration: Uncertainties

Dijet η inter-calibration

- MC Generator differences dominant uncertainty across pt and eta
  - Historically been > 10% source of uncertainty
- Small non-closure due detector mis-modelling in reconstruction software







Z/γ+jet Balance

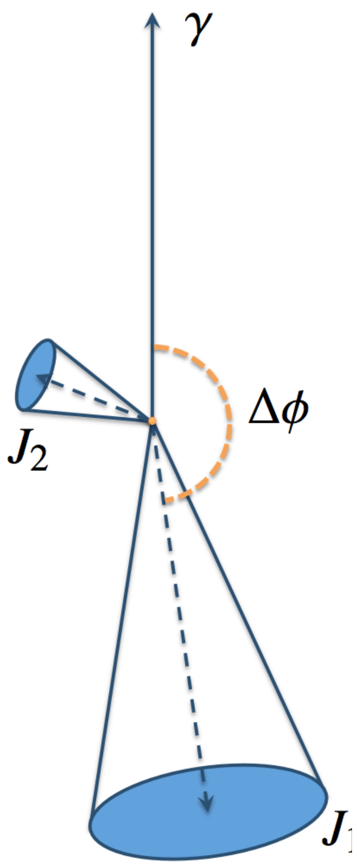
Z/γ+ jet Balance

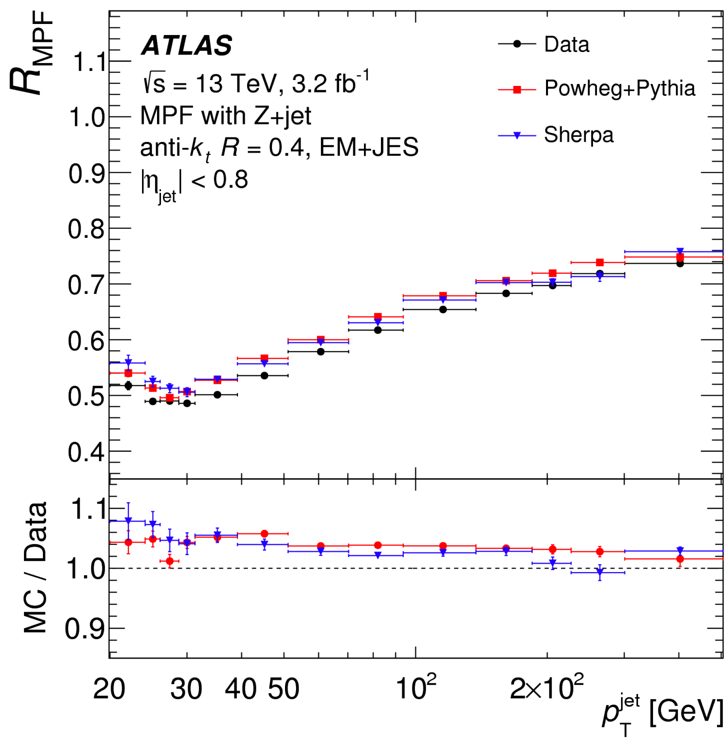
- **Reference object is a photon or Z boson**

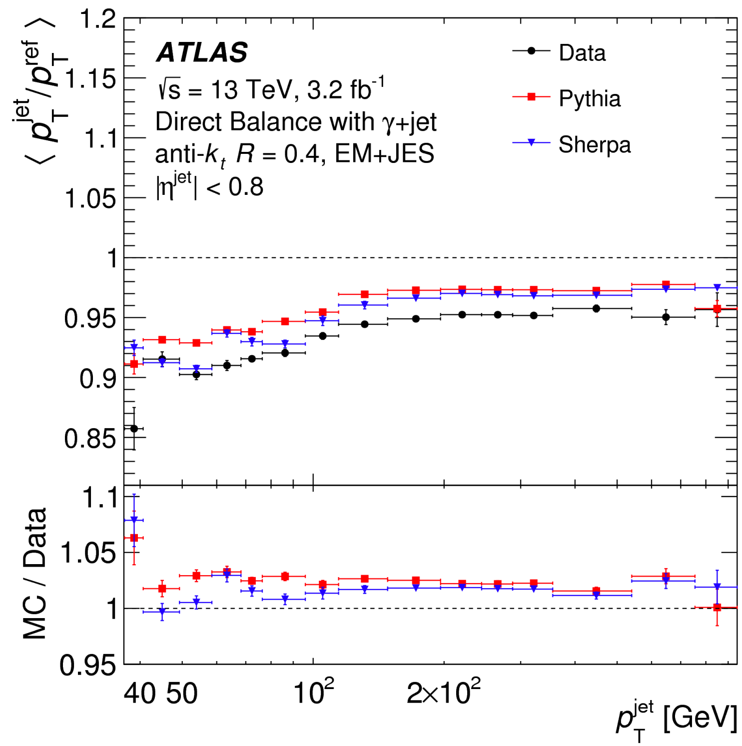
$$R^{\text{MPF}} = \left(1 + \frac{p_T^{Z/gamma} \cdot E_T^{\text{Miss}}}{|p_T^{Z/gamma}|^2}\right)$$

$$p_T^{\text{ref}} = p_T^{Z/\gamma} \times |\cos \Delta\phi(\text{jet}, Z/\gamma)|$$

- **Why?**
  - Correct for residual detector mis-modelling of pT

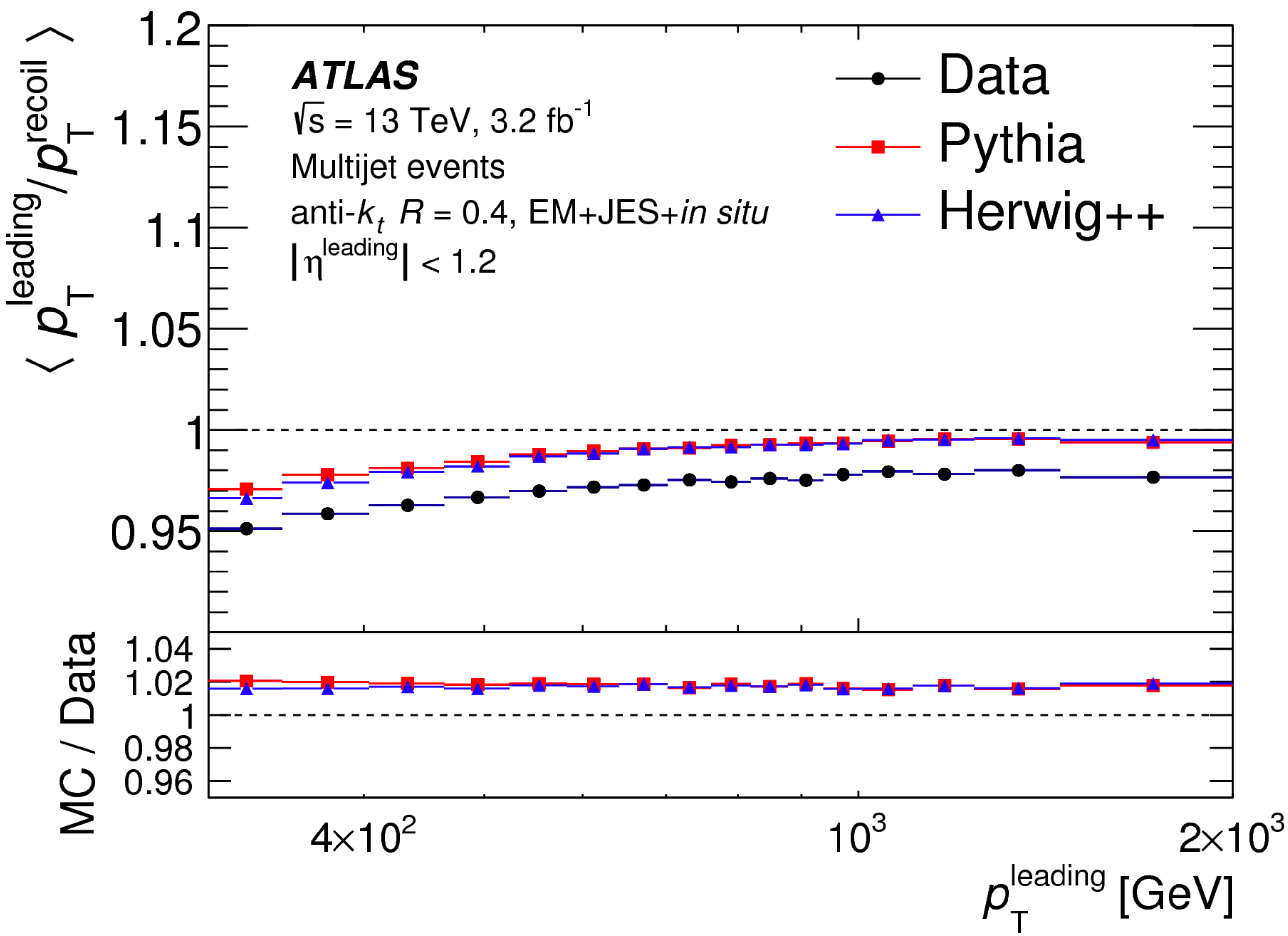


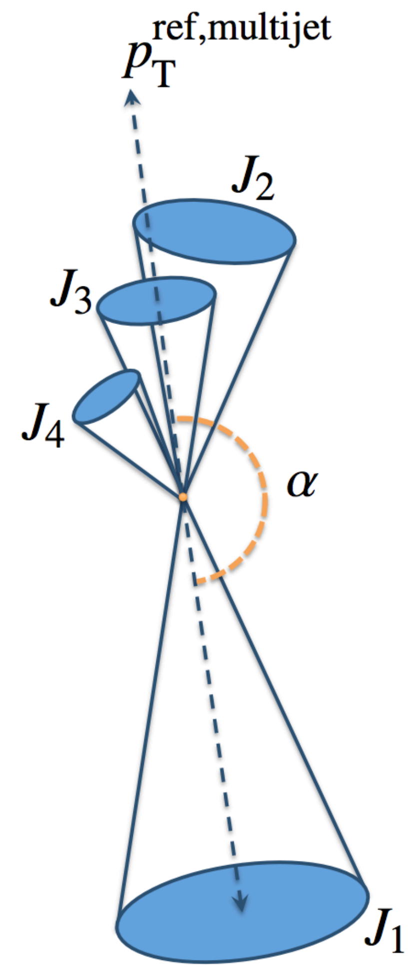




Multi-jet balance

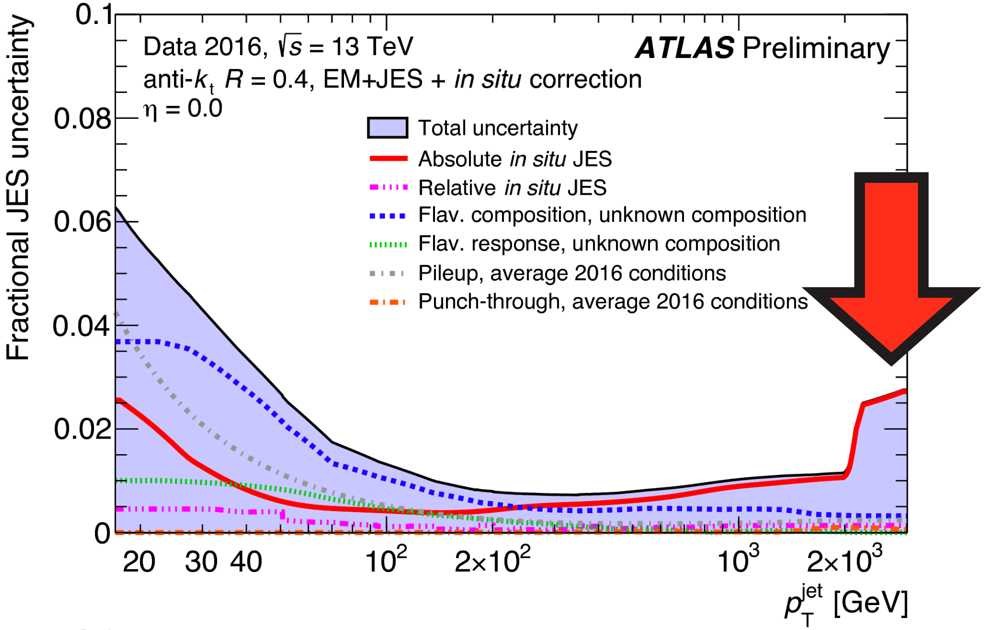
- **Reference objects are all low pT jets**
  - Other in situ corrections applied to low pT jet
- **Vital** for reduction of systematic uncertainty in JES for high pT jets

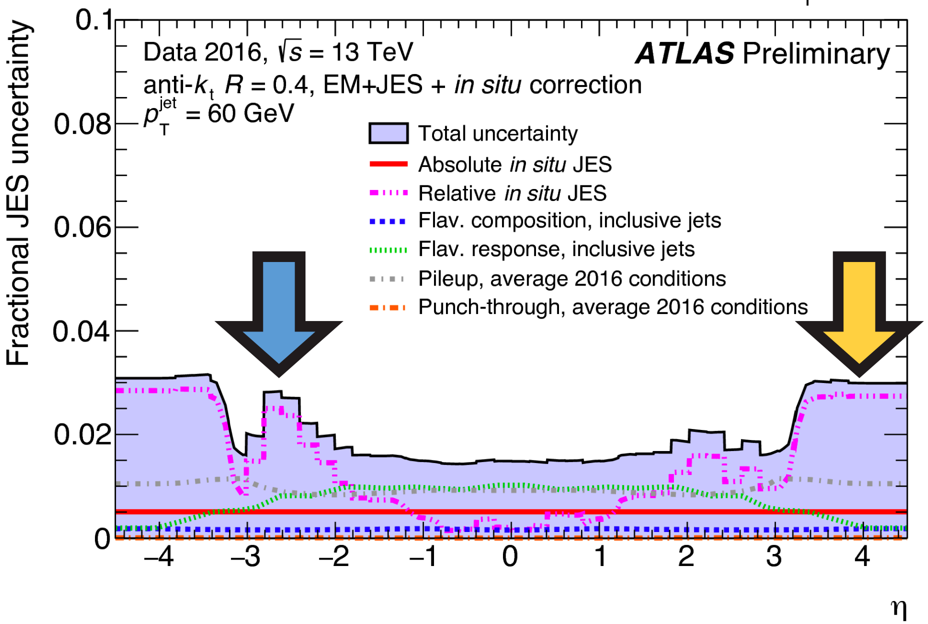




JES Uncertainties

JES Uncertainty: Sources

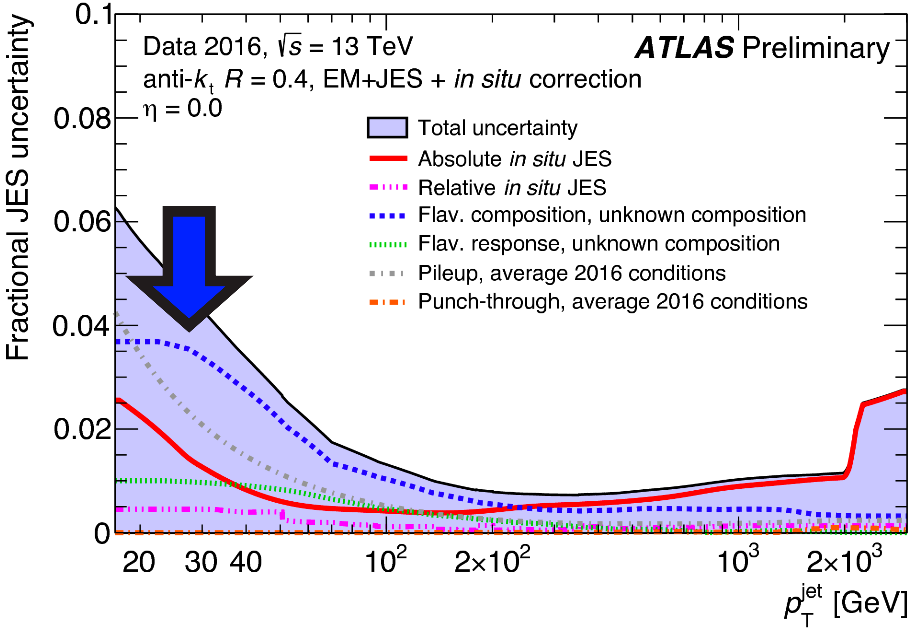


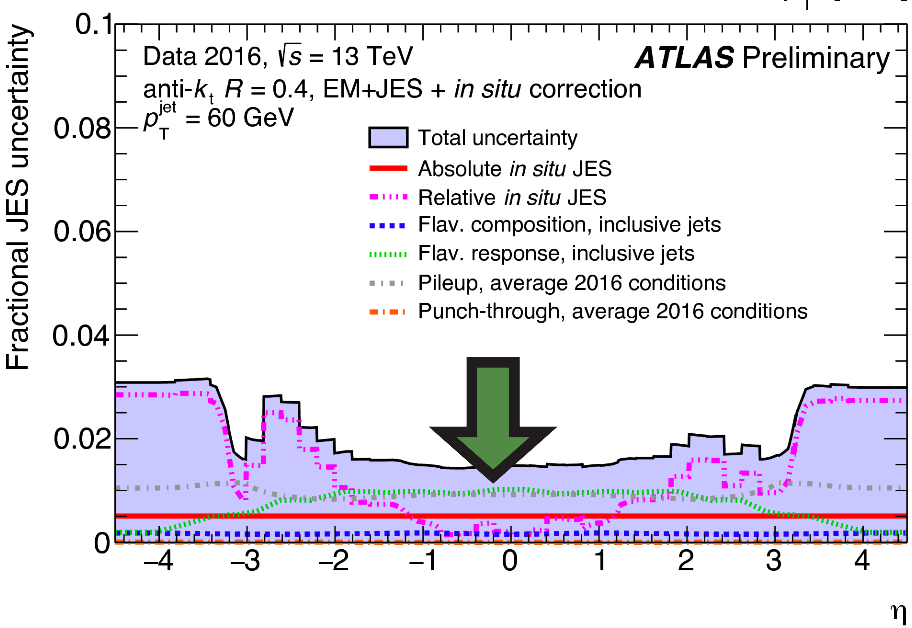


In situ uncertainty measurements

- Multijet balance technique running out of statistics
- eta inter-calibration dominant sources:
  - Non-closure
  - Mis-modelling

JES Uncertainty: Sources





Flavour uncertainties

- **Response**: Mis-modelling of the response of gluon/quark jet
- **Composition**: Topology dependent
  - Event level fraction of light quark-/b-/gluon-initiated jets.
  - Conservative 50/50 composition shown here

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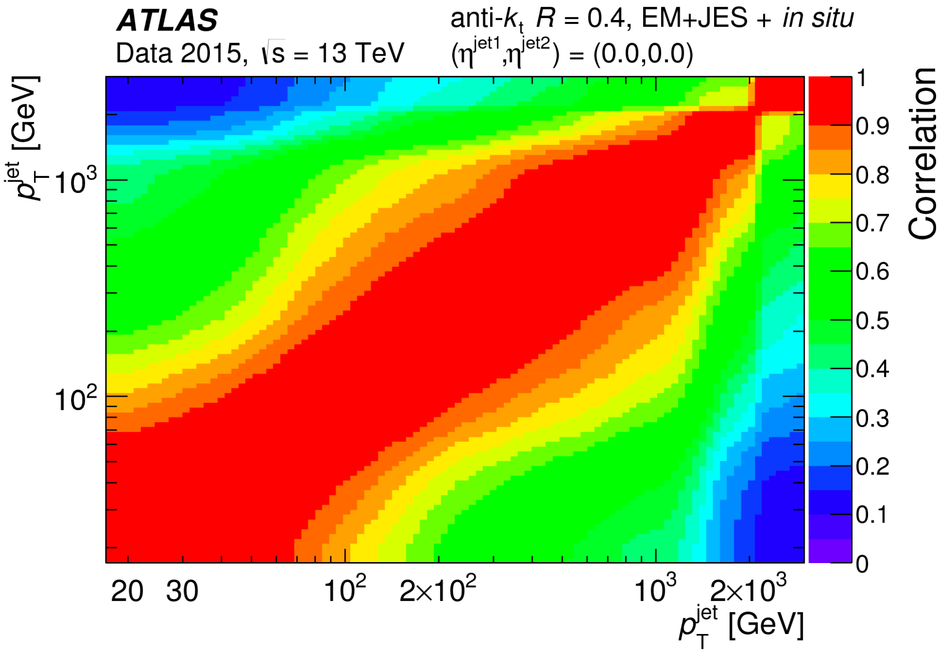
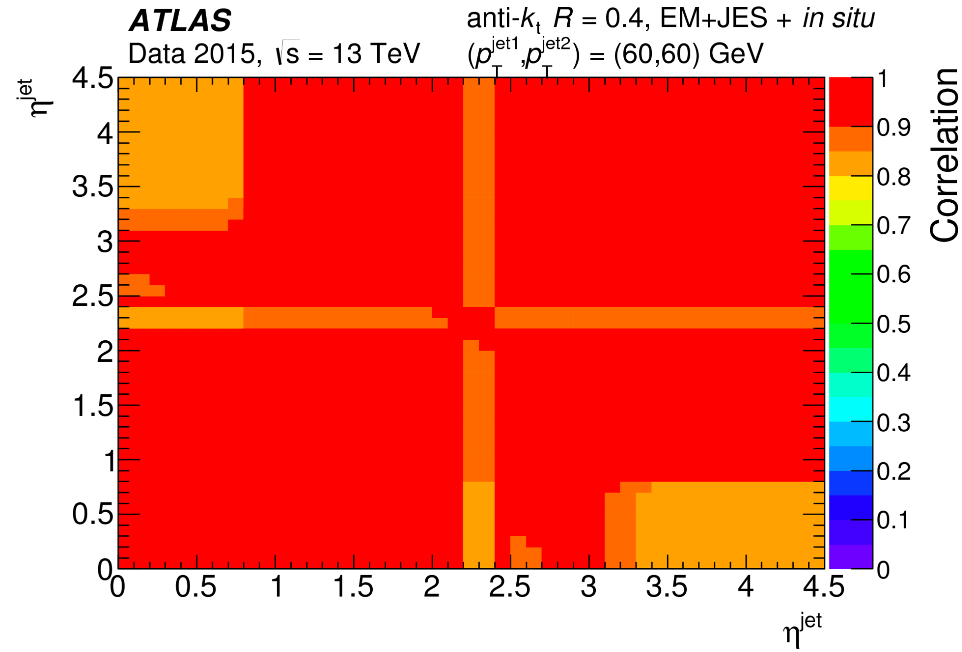
JES Uncertainty: Correlation





- 80+ Sources of uncertainty
  - In an ideal world would provide a single variation to the JES
- **Cannot do that** because of large correlation between pT and eta
  - Large correlations across eta mostly due to eta inter calibration
- Structure of in situ corrections visible in pT correlation
  - Gamma+jet becomes dominant contribution at ~100 GeV

Large-R Jets

Large-R Jets: in situ corrections

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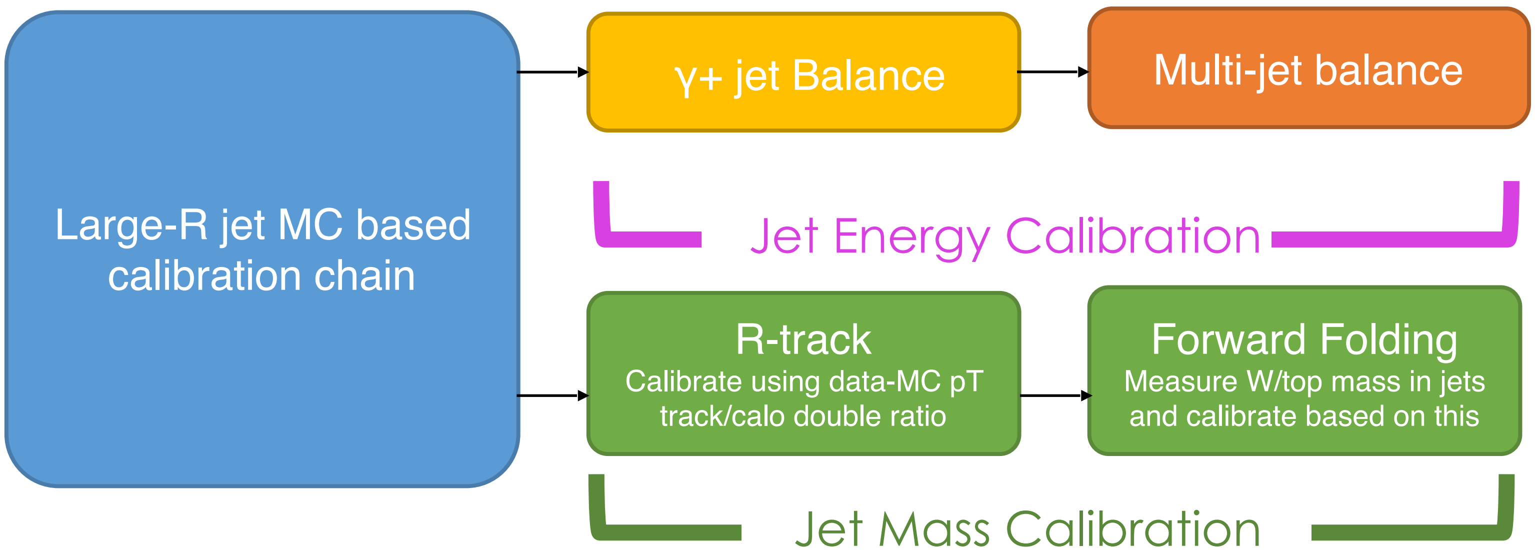
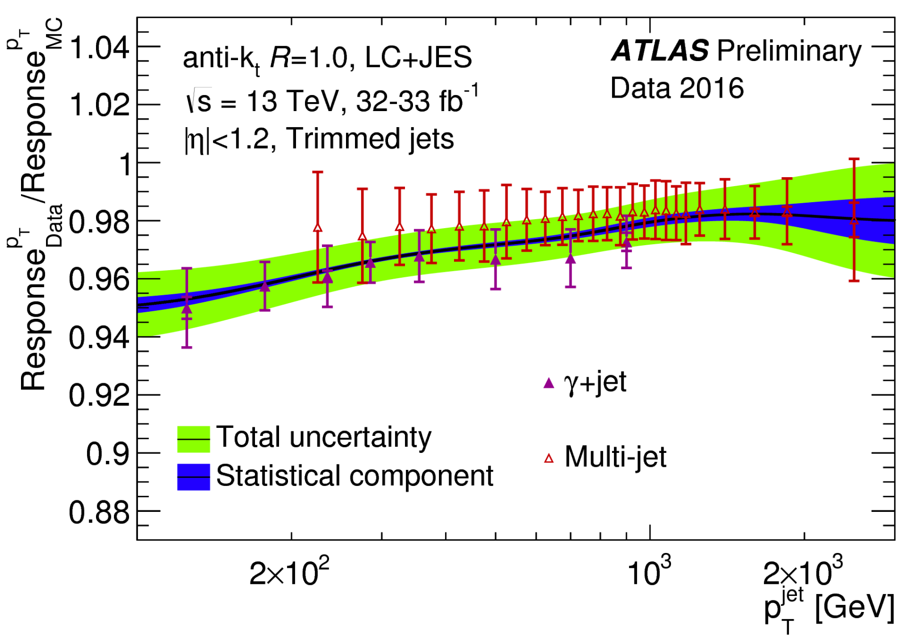
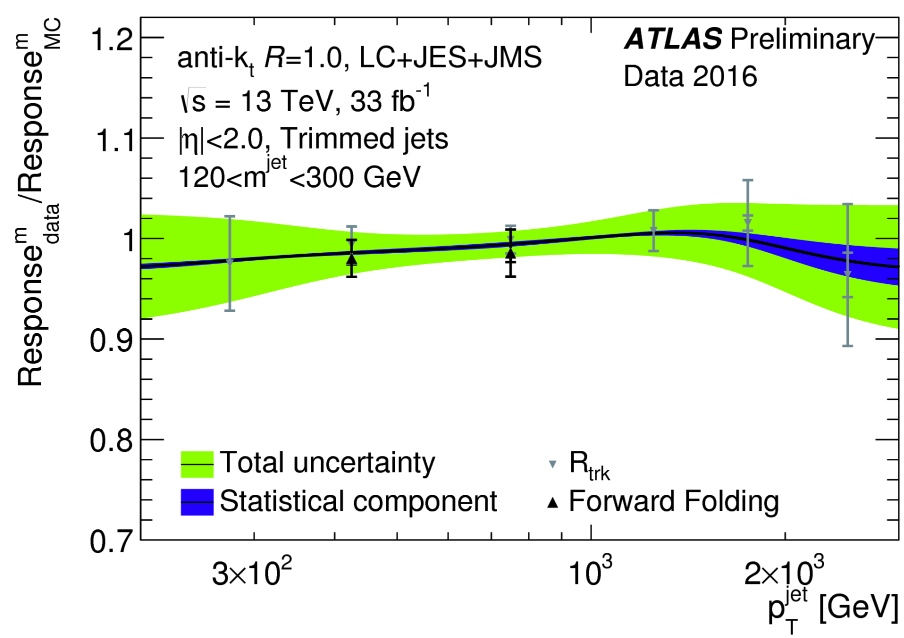
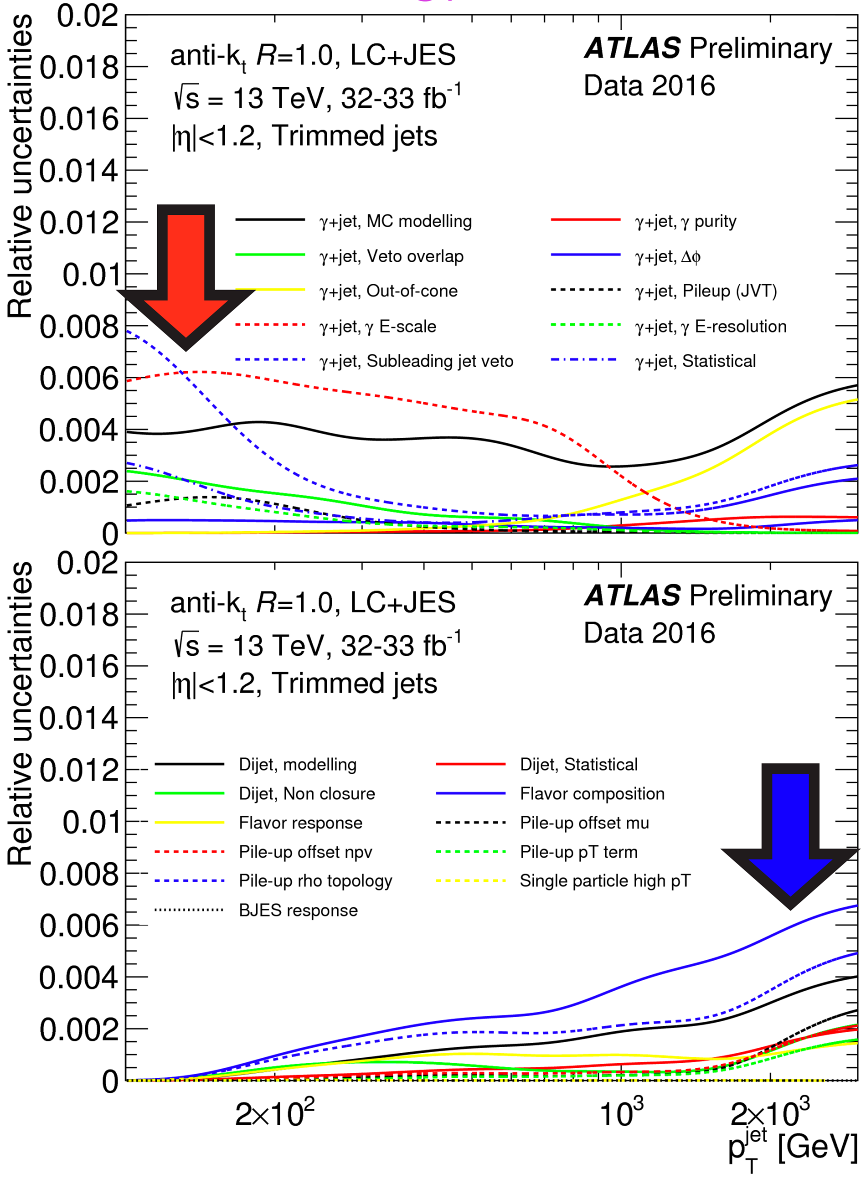




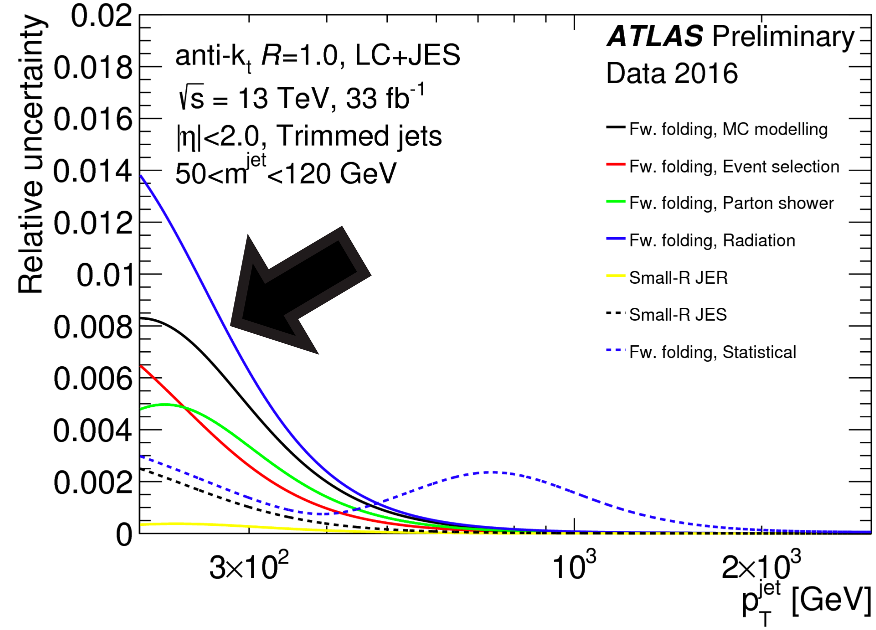


Large-R JES/JMS Uncertainty: Sources

Jet Energy Calibration



Jet Mass Calibration



- **JES uncertainties**
  - **Low pT**: photon energy scale uncertainties
  - **High-pt** dominated by flavour composition
- **JMS uncertainties**
  - Limited entirely by modelling of radiation, topology and shower

Summary

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- ATLAS has entered the era of precision jet physics
  - < 1% JES uncertainty for large regions of phase-space for small and large-R jets

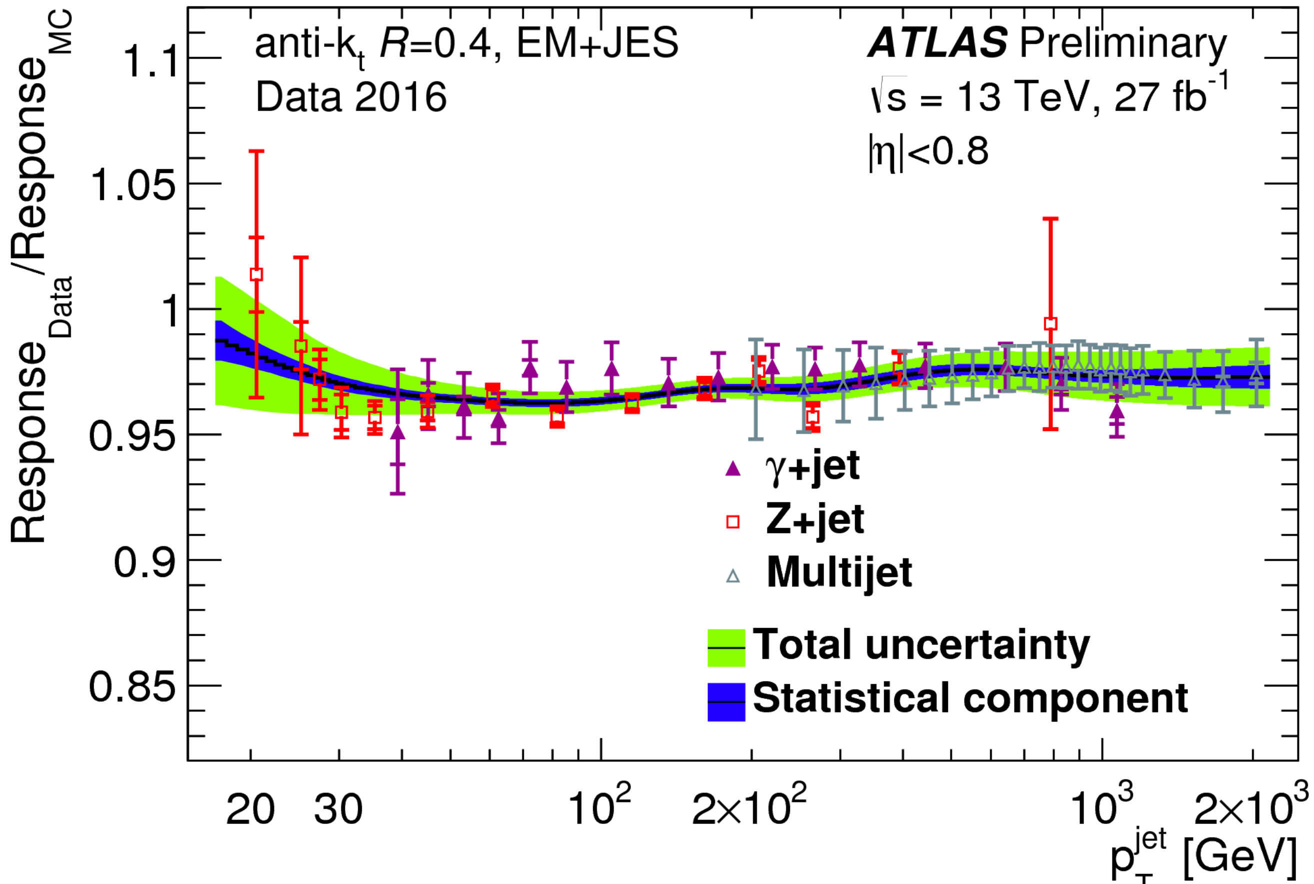
- Detailed understanding of the nature and sources of our uncertainties
  - Calibration and uncertainty assessed through a variety of complementary techniques
  - MC Mis-modelling a consistent and large source of uncertainty.

- Understanding of the JES uncertainty used to
  - Reduce flavour dependence
  - Simplify analyses

Thanks for listening!

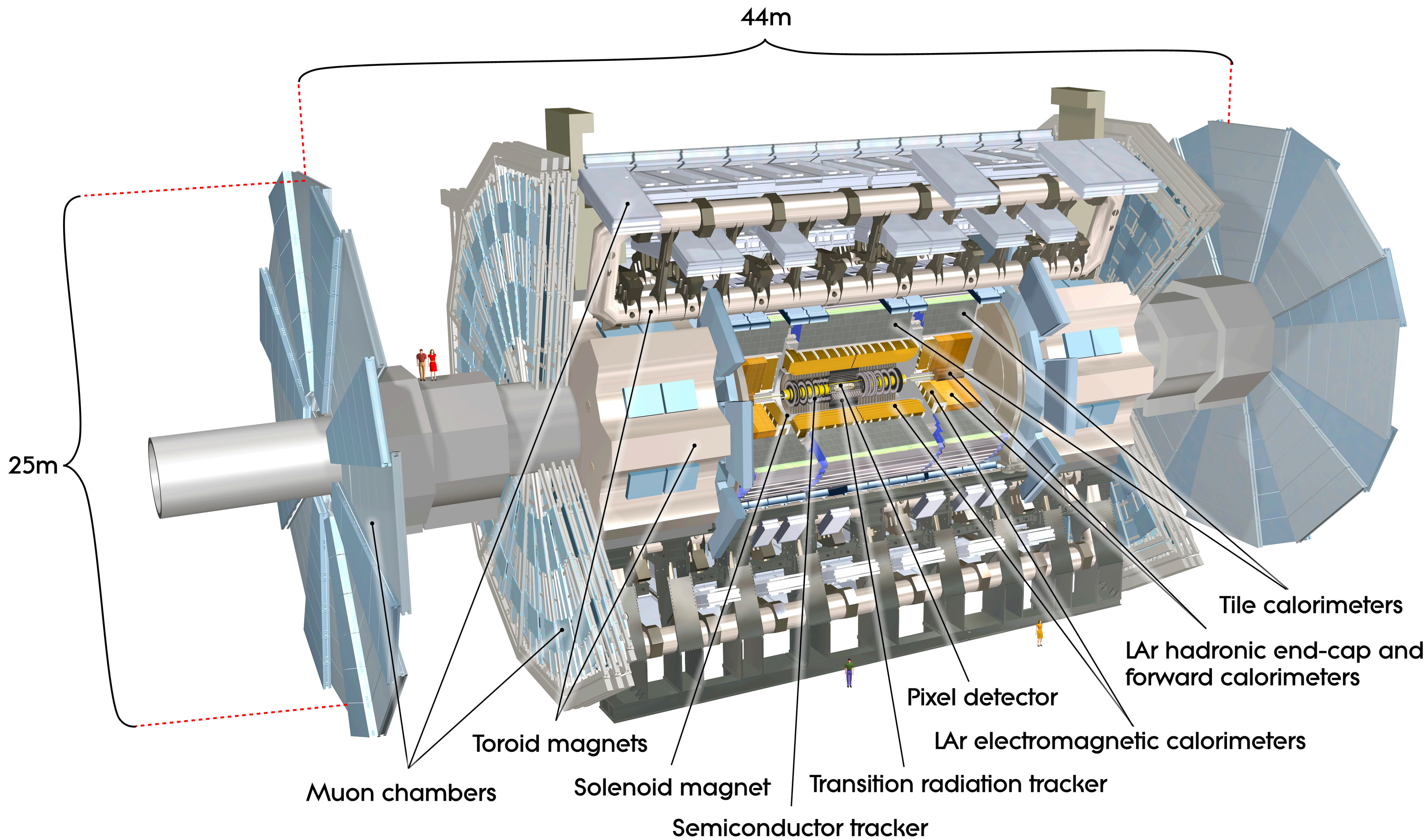
Back up

In-situ Calibration Combination

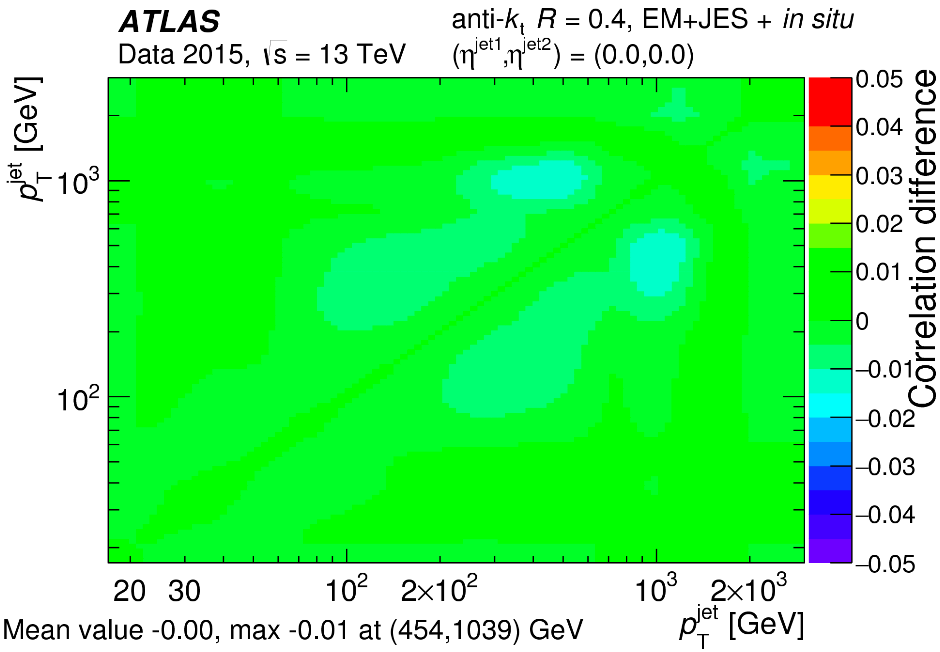


- **Goal:** Combined calibration that utilises all measurement
  - Chi2/NDoF of fit < 1 across all of pT
- Multiple combinations explored and found to be consistent
- Consistency across independent methods

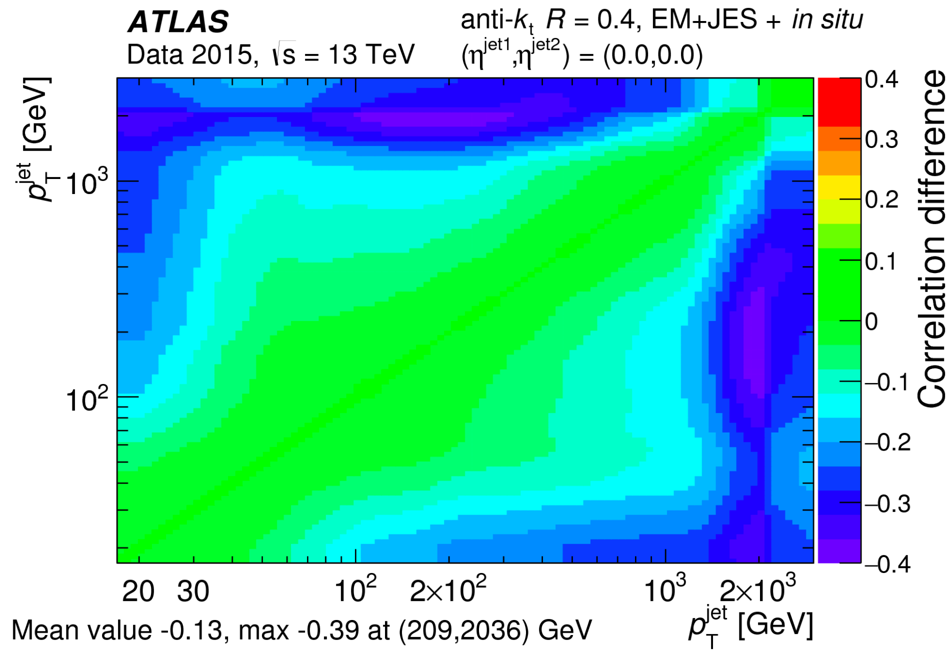
ATLAS Detector



JES Uncertainty: Eigenvector decomposition



Global reduction correlation loss



Strong reduction correlation loss

- Eigenvector decomposition of uncertainties - less systematics is more manageable for physics
- **Category Reduction:** Decompose sub-set of sources, retain physical meaning for most significant uncertainties - 19 sources
- **Global reduction: 21 eigenvectors**
- **Strong:** 4 eigenvectors
    - Large loss of correlation

Abstract

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- Hadronic jets are the key observable for studying QCD effects. The precise and accurate reconstruction of jets is therefore of paramount importance to the study of QCD effects. Additionally the uncertainty on the jet energy scale forms the major uncertainty in many measurements studying QCD effects. The correlations of these uncertainties across phase space and the degree to which they are known is published with our measurements and the understanding of these is paramount when making statements about the degree of agreement of various calculations with the data. This talk will describe the derivation of the jet energy scale in ATLAS using di-jet, vector boson, and multijet events. The origin of the uncertainties will be described and how these are treated as correlated or not across phase space. Uncertainty sources dominated by Monte Carlo modeling will have particular focus.